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ARTICLE 34 AMENDMENTS

121b, and respective flow passages 170a, 170b are positioned on/under the lower surface of pressure chamber 150. Accordingly, the thickness obtained by adding the thickness of pressure chamber 150 and the thickness of flow passages 170a, 170b means that the pump has a substantial thickness. The pump is incorporated in electronic equipment such as portable personal computers, and therefore it is desirable to make the pump thinner in order to reduce the thickness of electronic equipment.

Disclosure of Invention

[0010]

The present invention has its object to provide a diaphragm pump that enables an increase in pump efficiency by reducing the pressure loss of liquid and that enables reduction in thickness. Also, the present invention has its object to provide a cooling system that enables an increase in cooling efficiency by being provided with the diaphragm pump.

[0011]

To achieve the above-mentioned object, a diaphragm pump according to the present invention includes:

a pressure chamber formed into a flat shape and is filled up with liquid;

a suction side flow passage and a discharge side flow passage disposed at both ends of the pressure chamber so that axes thereof are aligned with each other and are connected with the pressure chamber;

at least one groove formed in a peripheral wall of the pressure chamber and for accelerating flow of the liquid downstream in a flow direction ; and

at least one diaphragm disposed on at least one of an upper surface

and a lower surface of the pressure chamber and for oscillation to make the volume of the pressure chamber variable.

[0012]

According to the present invention, the suction side flow passage and the discharge side flow passage are disposed at both ends of the pressure chamber so that the pressure chamber is sandwiched between the flow passages and the flow passages are connected with the pressure chamber. The suction side flow passage and the discharge side flow passage are extended in the same direction so that axes thereof are aligned with each other. Therefore, the flow passage for the pump, including the respective flow passages and the pressure chamber, is formed in a straight line without being bent, and thus the pressure loss of the liquid is reduced and the liquid flows efficiently. Additionally, since the pressure chamber is formed into a flat shape and, since the suction side flow passage and the discharge side flow passage are disposed at both ends of the pressure chamber, the whole of the pump is reduced in thickness. The diaphragm is arranged on at least one upper surface and the one down surface of the pressure chamber so as to operate on a surface having a large area in the flat-shaped pressure chamber, and thus oscillation by the diaphragm is transmitted to the pressure chamber efficiently. Therefore, the driving source is reduced in size, work is saved, and the size of the pump is also reduced. The groove may have a part with an opening in the upper surface facing the pressure chamber, into which the liquid flows, and a side part with an opening opened to a peripheral wall surface of the pressure chamber, from which the liquid is discharged downstream in the flow direction. Also, the groove may be extended in a radial direction while a point in the vicinity of the entrance of

the discharge side flow passage is set as a center. By arranging the groove, when pressure is applied to the pressure chamber by the diaphragm, the liquid is discharged from the part with an opening on a side downstream and the flow of the liquid is accelerated.

[0013]

Each of the flow passages may be formed so that the axes thereof are positioned at the center of a cross-sectional shape of the pressure chamber on a surface orthogonal to the axes. Accordingly, the flow of the liquid in the pressure chamber is even around the axes. With this arrangement, since the axes of the respective flow passages approximately pass through the center of the pressure chamber, the space in the pressure chamber is approximately symmetric relative to the axes. Accordingly, the flow passage of the liquid is approximately symmetric relative to the axes, and thus the pressure loss of the liquid in the pressure chamber is reduced.

[0014]

Each cross-sectional shape of flow passages and the pressure chamber is formed in an approximate rectangle in cross section. In this case, these can be formed by a cutting process or the like, and thus manufacturing is easy. In particular, when the lower surfaces of the flow passages and the pressure chamber are formed on the same surface, manufacturing is easy. Further, since the flow passage is made flatly, the liquid is circulated efficiently. In order to further reduce the pressure loss of the liquid, the length of the pressure chamber, viewed from an upper surface in a direction orthogonal to the axes, may be continuously shortened toward the suction side flow passage or toward the discharge side flow passage. Also, a height of the pressure chamber may be continuously lowered toward

the suction side flow passage or the discharge side flow passage. In both cases, the section of the pressure chamber is made smaller continuously toward the respective flow passages, and thus the pressure loss of the liquid in the pressure chamber is reduced.

[0015]

Also, the diaphragm pump according to the present invention may include check valves, respectively disposed on the suction side flow passage and the discharge side flow passage, and at least one of the check valves being tilted relative to the direction of the axes. Though the check valves are provided, the check valves are installed to tilt relative to the axial direction of the flow passage, namely, the flow direction of the liquid, and thus an increase in pressure loss is relatively reduced.

[0016]

The diaphragm pump may include: at least one intake opened to an upper surface of the suction side flow passage and is used to introduce bubbles mixed in the liquid; and a sealed space connected with the intake and is used to collect the introduced bubbles. The intake may be positioned in the suction side flow passage upstream relative to the check valve. Bubble collection means like this are arranged in this way, and thus the bubbles mixed in the liquid are collected and are prevented from entering the pressure chamber. In this way, by removing bubbles from the flow passages and the pressure chamber, the pressure loss of the liquid is further reduced. The intake is positioned in the suction side flow passage upstream relative to the check valve, and thus the bubbles are efficiently prevented from entering the pressure chamber.

[0017]

The diaphragm pump is a so-called piezoelectric pump in which the driving

applying an alternating voltage to piezoelectric oscillator 30 structured in this way, piezoelectric oscillator 30 bends and oscillate in the thickness direction of the plate.

[0032]

Lead zirconate titanate ceramic materials may be used, for example, as piezoelectric elements. The oscillating plate and the piezoelectric elements are bonded together by various techniques in accordance with the materials of the oscillating plate. For example, when ceramic or silicon is used as the oscillating plate, the piezoelectric elements can be integrated with the oscillating plate by a print firing method, a sputtering method, a sol-gel method, or a chemical vapor method. Incidentally, in the first embodiment, the piezoelectric elements are used as a driving source to oscillate the diaphragm, however, the driving source is not limited to piezoelectric elements and may be anything capable of oscillating the diaphragm.

[0033]

In suction side flow passage 70a and discharge side flow passage 70b, suction valve 20a and discharge valve 20b made of thin metal plates, such as aluminum, are respectively provided. Valves 20a, 20b are arranged so as to intersect diagonally the flow direction of liquid. As to both of valves 20a, 20b, upstream ends in the flow direction are supported by cantilevers and downstream ends are free ends abutting side walls of flow passages 70a, 70b without a water load. Accordingly, suction valve 20a opens suction side flow passage 70a when negative pressure is generated in pressure chamber 50, and closes flow passage 70a when positive pressure is generated in pressure chamber 50. On the other hand, discharge valve 20b closes flow passage 70b when negative pressure is generated in pressure

chamber 50, and opens flow passage 70b when positive pressure is generated.

[0034]

Additionally, sectional shapes of suction side flow passage 70a and discharge side flow passage 70b may be circles or so-called D-shapes in which a part of a circle is cut by a straight line. However, flow passages 70a, 70b are formed in a rectangle in the cross section as in the first embodiment, thereby forming valves 20a, 20b in simple shapes. Further, valves 20a, 20b can be attached by a relatively easy method, for example, by bonding one end of a valve member to one wall face in a flow passage.

[0035]

Next, explanations are given of the operation of piezoelectric pump 1 structured as described above.

[0036]

First, a voltage of a predetermined polarity is applied to piezoelectric oscillator 30, and piezoelectric oscillator 30 is displaced so as to have a convex upward orientation in Fig. 2. Then, the volume of pressure chamber 50 is increased, and the pressure in pressure chamber 50 becomes a negative pressure. With this operation, suction valve 20a is displaced and suction port 21a is opened, and the liquid flows into pressure chamber 50 via suction side flow passage 70a and suction port 21a. At this time, discharge valve 20b blocks discharge port 21b, and no liquid flows from discharge port 21b.

[0037]

Successively, a voltage of an inverse polarity to the above polarity is applied to piezoelectric oscillator 30, and piezoelectric oscillator 30 is

flow direction of the liquid. Accordingly, compared with a valve arranged orthogonally to the flow direction, suction valve 20a and discharge valve 20b are displaced with a small force, and the pressure loss of the liquid can be further reduced. As described above, piezoelectric pump 1 is improved in pump efficiency compared with the conventional one, and cooling system 10 (refer to Fig. 1) is also improved in cooling efficiency with the improvement in pump efficiency. Incidentally, in the first embodiment, both suction valve 20a and discharge valve 20b are tilted relative to the flow direction, however, it is possible to tilt only one discharge valve.

[0040]

Also, in the first embodiment, since flow passages 70a, 70b are positioned at both ends of pressure chamber 50, the flow passage is formed into a flat shape and the whole of piezoelectric pump 1 is reduced in thickness. Further, since piezoelectric oscillator 30 is arranged so as to operate on one surface that has the large area of pressure chamber 50 formed in a flat rectangular parallelepiped shape, the bending displacement of piezoelectric oscillator 30 can be transmitted to pressure chamber 50 efficiently. Accordingly, relatively small piezoelectric oscillator 30 can obtain a sufficient amount of flow, and piezoelectric pump 1 can be reduced in size as a result. Additionally, in the first embodiment, one piezoelectric oscillator 30 is arranged on the upper surface of pressure chamber 50, however, the number of piezoelectric oscillators and their shape thereof are not limited. For example, two piezoelectric oscillators are arranged for upper and lower surfaces of pressure chamber 50.

[0041]

As described above, cooling system 10 using piezoelectric pump 1

enabling a reduction in thickness and an increase in pump efficiency can circulate the liquid efficiently. Further, for example, by arranging heating parts directly to or in the vicinity of flow passage unit 60, heat from the parts can be dissipated efficiently.

[0042] (Second Embodiment)

In the first embodiment, the pressure chamber is formed in a rectangular parallelepiped shape, however, the pressure chamber may be formed so that the cross-sectional area of the pressure chamber is gradually varied in order to reduce the resistance of the liquid.

[0043]

Fig. 3 shows the piezoelectric pump of the second embodiment according to the present invention. Piezoelectric pump 2 shown in Fig. 3 is formed so that pressure chamber 50' is formed in a streamlined shape. On peripheral walls of pressure chamber 50', structural parts (retuning grooves 11a) for accelerating the flow of the liquid are arranged. The other structures are similar those of piezoelectric pump 1 shown in Fig. 2, and the same numeral references are applied to the structural parts having the same functions and explanations thereof are omitted.

[0044]

Pressure chamber 50', as shown in Fig. 3(b), is provided with peripheral wall surface 11e in an approximate streamlined shape viewed from the upper surface. Peripheral wall surface 11e is arranged vertically to bottom part 11b of pressure chamber 50'. Also, peripheral wall surfaces 11e are respectively connected with suction port 21a and discharge port 21b, and are bent in an arc shape toward the outside. Incidentally, the arc shape is preferably set, as appropriate, in accordance with the kind of liquid or

[0057]

Gaseous chamber 35 is formed by piezoelectric oscillator 30 and by the cabinet of piezoelectric pump 3, and covers suction side flow passage 70a and discharge side flow passage 70b.

[0058]

At the somewhat upstream side to suction valve 20a, one intake 35a for introducing bubbles into gaseous chamber 35 is arranged. Intake 35 is a hole for connecting suction side flow passage 70a and gaseous chamber 35 and is positioned on the upper surface of suction side flow passage 70a.

[0059]

When piezoelectric pump 3 is applied to the cooling system shown in Fig. 1, a closed-structure flow passage is formed by the flow passage in cooling system 10 and gaseous chamber 35. Then, the flow passage is completely filled up with the liquid to be circulated. In other words, in the initial state of cooling system 10, gaseous chamber 35 is also filled up with the liquid.

[0060]

In cooling system 10 structured like this, when bubbles are generated in the liquid, the bubbles move through circulation flow passage 60a (refer to Fig. 1) by the flow of the liquid. Then, the bubbles which have moved along the upper wall of suction side flow passage 70a are taken into intake 35a and float upward. At the same time, the liquid in gaseous chamber 35 is pushed out from intake 35a by the bubbles, and the bubbles are collected in gaseous chamber 35. With this operation, in piezoelectric pump 3, the bubbles can be removed from the flow passage in cooling system 10, and the liquid can be circulated without a reduction in pump efficiency.

[0061]

Incidentally, in the third embodiment, as shown in Fig. 7(b), the opening shape of the opening in intake 35a is formed in a circle. The shape of the opening in intake 35a is not limited to this as long as bubbles can be collected, for example, an oblong hole (not shown) extending in the width direction of suction side flow passage 70a may be formed. With this arrangement, bubbles moving along the upper wall of flow passage 70a can be collected efficiently. Further, when two intakes are arranged, bubbles enter gaseous chamber 35 through one of the intakes while liquid is discharged from the other intake. In this way, the operation of exchanging bubbles and liquid may be performed smoothly. Also, needless to say, in order to collect bubbles efficiently, intake 35a may be arranged so as to be higher relative to flow passage 70a. And a groove or a part that has been shaped for guiding the bubbles to intake 35a may be formed.

[0062]

Additionally, piezoelectric pump according to the third embodiment may be variously changed as shown Figs. 8 and 9. In piezoelectric pump 3' in Fig. 8, piezoelectric oscillator 30 is arranged on the lower surface of pressure chamber 50. In piezoelectric pump 3" in Fig. 9, gaseous chamber 35" is arranged in a loop area. Both of piezoelectric pumps 3', 3" are not different from piezoelectric pumps 3 substantially, and gaseous chambers 35, 35', 35" function similarly.

[0063]

As described above, according to the third embodiment, piezoelectric pump 3 is provided with gaseous chamber 35, and bubbles generated in liquid can be collected. Therefore, piezoelectric pump 3 is improved in pump